# Serrated Light Illumination for Deflection Encoded Recording (SLIDER)

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Ultrafast, high dynamic range, single-shot diagnostics are critical to performing experiments in high-energy-density physics (HEDP). In recent years, conventional single-shot recording instrumentation has undergone minor incremental performance improvements. This instrumentation is largely based upon oscilloscopes and streak cameras that are fundamentally limited to trading off dynamic range for temporal resolution and do not scale well into the ps regime. More recently developed ultrafast optical methods can achieve 0.01 ps resolution but only over short record lengths of a few ps. No current technology is aptly suited for high dynamic range measurement in the 1 to 100 ps regime.

Figure 2. Fabricated 1-cm-x-2-cm SLIDER deflector consisting of a gold patterned coating on a GaAs waveguide. The prism array is manifested as a continuous gradient because the 60-μm pitch is too fine to be resolved.

In this project, we address this technology gap by demonstrating a novel technique for single-shot recording of optical signals that is extendable to x rays. Using an auxiliary pump beam and a serrated mask, a prism array pattern is optically imprinted onto the guiding channel of a semiconductor waveguide. The transient prism array deflects signals in a stepwise manner linearly encoding time into multiple angular channels. A slow camera in the back focal plane of a cylindrical lens is used to record the swept signal in parallel with high dynamic range (Fig. 1).

## Project Goals

We aim to demonstrate an all-optical analog of the conventional streak camera that can meet upcoming HEDP end-user requirements. Specifically, our goal is to demonstrate the SLIDER concept for single-shot, high dynamic range recording (>8 bits) in a temporal regime (1 to 100 ps) that currently does not have any strong technology base. The technique leverages a wide body of research on ultrafast all-optical phenomena in semiconductors and combines it with well-established high dynamic range camera technology.

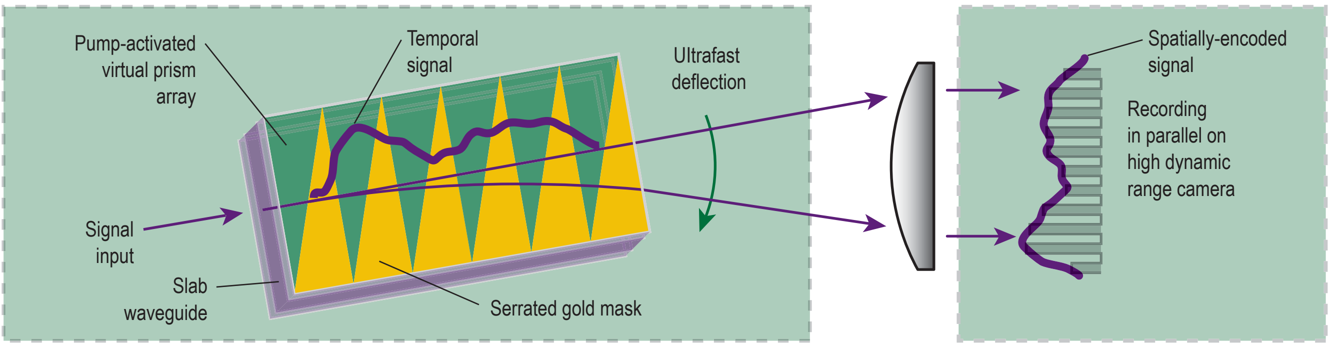


Figure 1. Schematic illustrating the SLIDER concept. The concept is based on the optically-induced deflection of an optical signal propagating in a slab waveguide. The deflection is caused by a sequential array of transient prisms that are created by a pump beam applied perpendicular to the guide through a serrated mask. The tradeoff between temporal resolution and dynamic range in traditional recording instruments is decoupled here by implementing ultrafast nonlinear mechanisms for the sweep followed by recording on a high dynamic range camera.

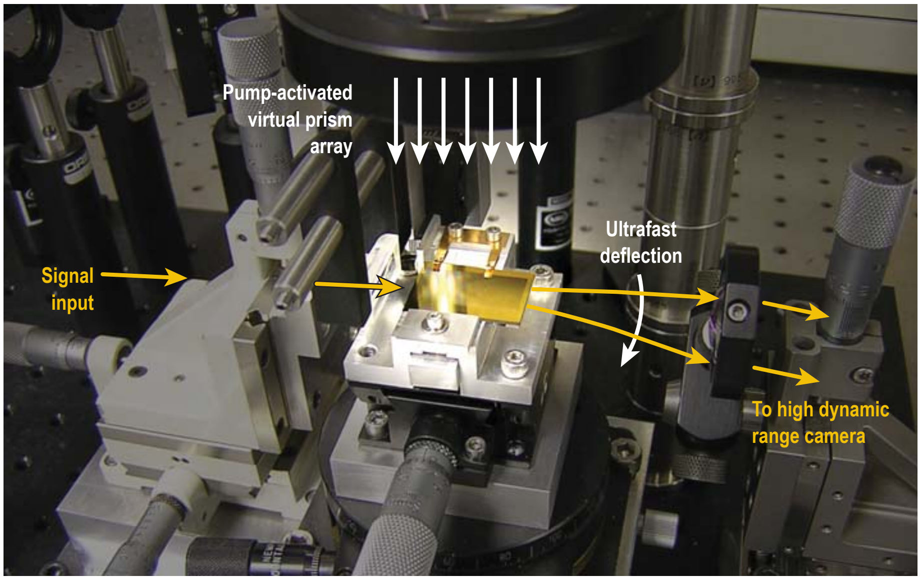


Figure 3. Experimental testbed setup showing the SLIDER deflector mounted in a multi-axis coupling stage. The signal and pump beam pathways are illustrated.

## Relevance to LLNL Mission

The proposed work directly addresses instrumentation performance gaps in engineering at LLNL. Future WCI and NIF experiments will require single-shot, high-dynamic range characterization of fusion burn histories.

## FY2007 Accomplishments and Results

We fabricated and tested a SLIDER device (Fig. 2) constructed from a 0.6-µm core GaAs planar slab waveguide. A gold serrated mask was patterned sufficiently far above (1.2 µm) the core so as to not perturb the guided signal, yet close enough such that diffraction of the illuminating pump beam was negligible. A 60-µm prism array pitch ensured sub-ps temporal discretization into deflection encoded channels.

An ultrafast Ti:Sapphire based oscillator and chirped pulse regenerative amplifier provided a 0.15-ps pump pulse at 800 nm. This wavelength is suitably above the bandgap of GaAs to be strongly absorbing in the guiding layer generating electron-hole pairs that subsequently alter the refractive index in a transient manner.

Part of the pulse energy was tapped off to drive an optical parametric amplifier (OPA) that generated an idler beam at 1920 nm that was subsequently frequency-doubled to 960 nm for use as a test signal beam. This wavelength was chosen to optimize the pump-induced modification of the refractive index of GaAs resulting from the interplay of the plasma effect, charge screening, and the Burstein-Moss effect. A ringdown test pattern consisting of ~1 ps pulses separated at 10-ps was used for a proof-of-concept.

Figure 3 shows the experimental testbed setup. A cylindrical lens was used to couple the 1-cm test signal beam into the waveguide. Cylindrical lenses on the output end focused the beam to a nearly diffraction limited spot. The pump beam was expanded and applied perpendicularly to the guiding channel passing first through the serrated mask. The pump and signal pulses were synchronized by use of a motorized delay stage.

A recorded single-shot trace is shown in Fig. 4.

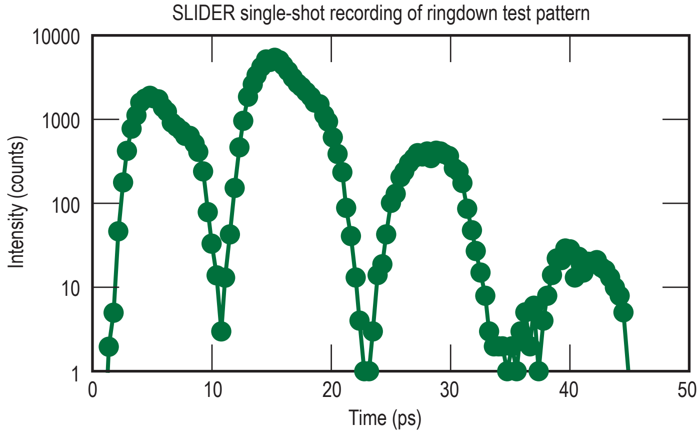


Figure 4. Recorded single-shot trace of a ringdown test pattern of ~1-ps pulses derived from a Gires-Tournois cavity with a 10-ps round trip time. The measured resolution is 3–4 ps FWHM and the dynamic range is in excess of 1000.

## Related References

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## FY2008 Proposed Work

We plan to conduct a detailed characterization of the merits and drawbacks of the SLIDER concept with a refined device. Numerous technical challenges remain before the proof-of-concept can be turned into a working instrument. Primary technical challenges include overcoming dynamic absorption (free-carrier and two-photon) and pump beam nonuniformities. We will further study the feasibility of combining SLIDER with an x-ray-to-optical converter for characterizing fusion burn histories on NIF.